Probing trap depths in persistent phosphors

Koen Van den Eeckhout[1], Adrie J.J. Bos[2], Dirk Poelman[1] and Philippe F. Smet[1]

[1] LumiLab, Department of Solid State Sciences, Ghent University, Ghent, Belgium
[2] Faculty of Applied Sciences, Delft University of Technology, Delft, The Netherlands

Contrary to normal luminescent materials, persistent phosphors are able to continue their light emission for hours after the end of the excitation [1]. This has applications for emergency signage, dials and displays, decoration, and more recently also for *in vivo* medical imaging [2]. Research into this class of phosphors has seen a dramatic increase during the past decade, but the development of new and brighter afterglow materials is hampered by a lack of understanding of the underlying mechanisms. Although the general principles of excitation and charge trapping are agreed upon, important details such as the nature of the traps, the optimal trap depth and the kinetics of the (de)trapping processes involved remain the subject of ongoing debate.

Thermoluminescence (TL) experiments have become increasingly popular over the past fifteen years to study the trap system in persistent luminescent materials. However, in most of these materials multiple trap levels are present, which complicates the glow curve analysis. Furthermore, only a small range of trap depths is suitable for achieving a bright afterglow at room temperature, and the glow peaks often strongly overlap in this region, making it nearly impossible to use standard fitting procedures. A single TL glow curve is therefore unreliable for the determination of trap depths and concentrations. Different sets of TL measurements should be combined with specific analysis techniques.

We investigated the influence of various parameters such as the heating rate, the excitation intensity and the excitation temperature on both the afterglow decay and the TL glow curves in persistent luminescent materials and apply it to the case of the violet-emitting $CaAl_2O_4$:Eu,Nd persistent phosphor (see Fig. 1). Evidence was found for the presence of a trap depth distribution rather than discrete energy levels, and the possibility of higher order kinetics is discussed.

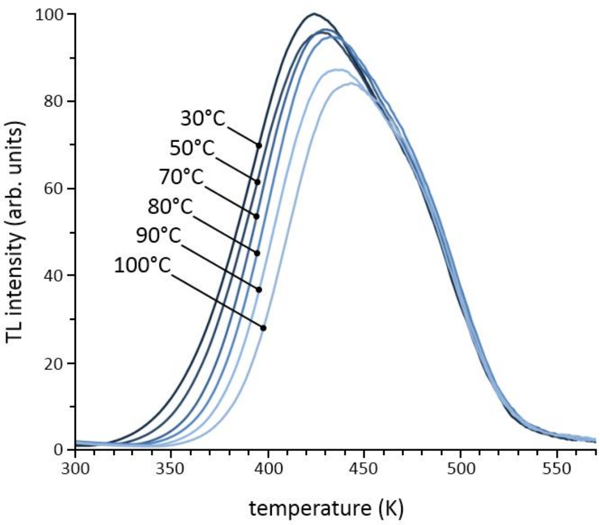

Figure 1: Variation of the excitation temperature shows a behaviour of the TL glow curves of $CaAl_2O_4$:Eu,Nd which cannot be explained with a simple one trap - one luminescent center model.

[1] K. Van den Eeckhout *et al.*, *Materials* **3** (2010) 2536-2566
[2] T. Maldiney *et al.*, *Optical Materials Express* **2** (2012) 261-268